NEW APPARATUS FOR ACOUSTICAL EXPERIMENTS[1]

By M. BENTLEY, E. G. BORING, and C. R. RUCKMICH

Sound-Localisation Apparatus

(Fig. 1)

While this apparatus was originally designed and built for the purpose of localising pure tones, it is, nevertheless, suitable for localising noises as well. It consists, first, of a rod (*a*) of ½″ gas-piping, bent to an arc of 120 degrees of a circle 3 feet in radius. This rod is fitted into a vanadium steel plate, shown at (*b*), which moves noiselessly and readily on a ball-bearing runway above and below it and between two stationary steel plates (*c* and *d*) of the same diameter (4 inches). All three plates are fastened together by means of a bolt, seen at *e*, ¾″ in diameter and 6″ long, which screws into an angle-plate (*f*) above it. A lock-screw holds the bolt in place. The angle-plate fits the lower end of a 4″ x 6″ beam (*g*) that reaches to the ceiling of the large room in which the apparatus stands. On the revolving plate which carries the curved rod is fastened a brass disc (*h*) 1/16″ thick and 6″ in diameter. Upon this disc are painted in black on a background of white enamel marks which indicate in degrees of rotation the position of the curved rod in the horizontal plane. A blued steel pointer fastened on the lower stationary plate gives the precise reading. Along the curved rod (*a*), which is also marked in degrees of position in the vertical plane, is fastened a movable and adjustable coupling (*i*). This coupling allows a brass rod (*j*) ⅜″ in diameter and 4′ long, to move radially in and out from the arc and at right angles to the tangent of the arc at that point. The coupling with its brass rod can also be placed in any position on the curved arc; *i.e.*, it can be placed anywhere along the circumference of the circle in the vertical plane. On one end of this brass rod an adjustable clasp (*k*) is fastened. The clamp is primarily designed to hold an electrically operated tuning fork and re-

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[1] From the Psychological Laboratory in Arts, Cornell University. With the exception of the pendulum-control for the rhythm-box and a part of the interruptor, fashioned by Mr. Ruckmich, the pieces described have been made from the Department's plans and models by Mr. C. N. Harding, of the firm of Messrs. Kellogg & Harding, 108 North Cayuga St., Ithaca, N. Y.—M. B.

sonator, indicated at *l*, but may hold any other electrically driven device for the production of sound. One electric connection is made with the fork through the metal frame of the apparatus, the other through a flexible lamp-cord to a wheel contact (*m*), moving along an insulated track at the bottom of the supporting beam. This method of connection obviates the difficulty of twisting the connecting wires as the apparatus rotates. Both the weight of the fork and the weight of the revolving curved rod are suitably counterbalanced by means of adjustable counterweights (*n* and *o*). The observer sits in a cushioned chair with his head in a head-rest, seen at *p*. His ears are approximately at the center of the circle of which the curved rod forms an arc, and opposite the open end of the resonance-box. The varying height of observers is accommodated by raising or lowering the chair. In front of the observer's head is mounted a 4 c. p. incandescent light (*q*), seen through the closed eye-lids and operated by the experimenter as a 'now' signal. The connections from the fork pass along the ceiling, and from the signal light through a socket in the floor, to a writing desk (*r*), equipped with a shaded reading-lamp and two switches, one for the fork and one for the signal light. The desk is over nine feet from the observer and the switches mounted on it are noiselessly operated by the experimenter. The connections pass on to an adjoining room separated from the experimenter's room by a stone wall two feet in thickness. In this adjoining room, a Helmholtz exciting-fork electrically driven is set up. It is connected in shunt circuit with the secondary fork and has a vibration rate two octaves below the secondary fork. It was necessary to connect it in a shunt circuit because it was inconvenient to pass into the adjoining room to start the exciting-fork after the operating switch was pulled at the end of every judgment.

The apparatus has, among others, four advantages: (1) it makes possible experimentation with a pure tone, and the avoidance of various secondary criteria, viz., rustling of experimenter's clothing, noise of footsteps, sounds from breathing, etc.; (2) it covers every advantageous point in the tridimensional manifold, because the fork can be moved in and out with regard to the observer's ear from proximity to a distance of about six feet;—this outer limit is reached by swinging the brass rod, which carries the fork, around outside of the curved rod that marks the circumferential boundary of the three-foot circle; (3) on account of the noiseless bearing above, where the apparatus is attached to the supporting

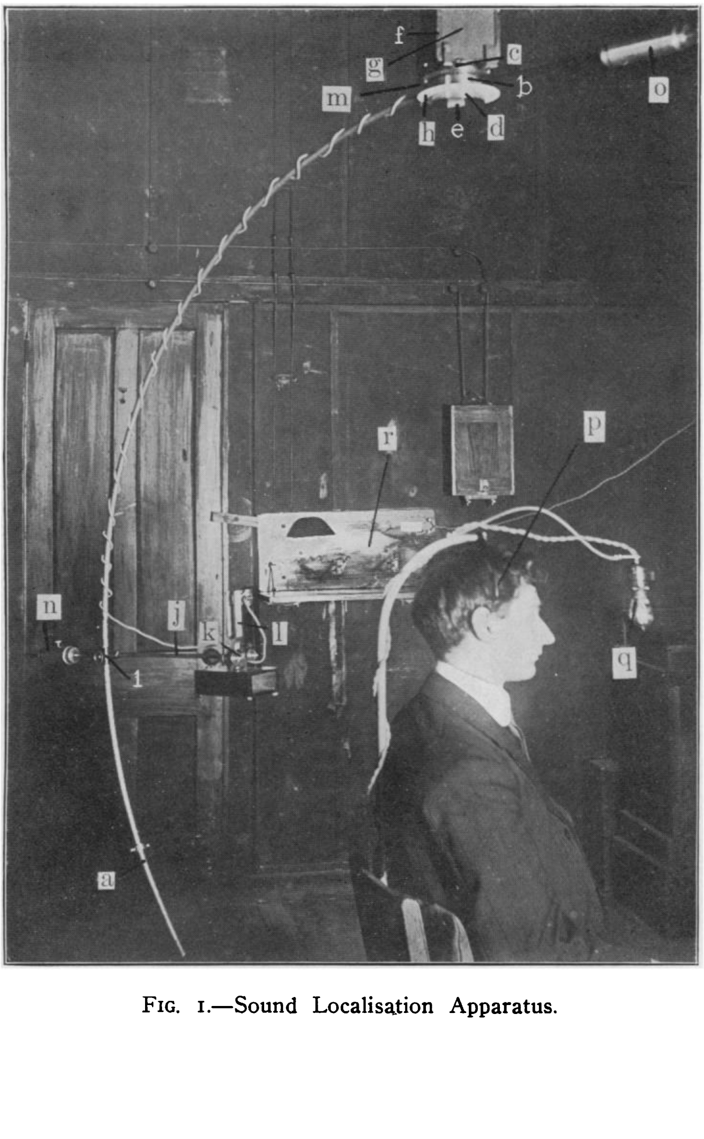

FIG. 1.—Sound Localisation Apparatus.

beam, and because of the impossibility of twisting the circuit wires during rotation, it is suitable for experimentation with a moving stimulus; and (4) inasmuch as there is no mechanical connection with the chair and head rest, disturbances attending the adjustment of the apparatus are not communicated to the observer.

Rhythm Interruptor

(Fig. 2)

This device is a part of the general apparatus used in an investigation of the rhythm-consciousness. It was designed to interrupt the secondary (receiver) circuit of a telephonic system. The demands upon the apparatus were eight in number: (1) The apparatus should rotate at a constant rate of speed, (2) its speed should be variable at the experimenter's wish, (3) its speed should be easily measurable, (4) the apparatus should produce a rapid interruption of a telephonic circuit, (5) during intervals between interruption, there should be the best possible electrical contact, (6) there should be a simple and accurate method of varying the temporal length of intervals of contact and of non-contact, corresponding to the length of members and of pauses between members of a rhythmic series, (7) these periods of contact and of non-contact should be subject to accurate measurement, and (8) both long and short intervals, *i.e.*, those between groups of members and those between members of a rhythmic series, respectively, should be of constant temporal length, regardless of the change in the duration of the individual members of the rhythm. To meet the first requirement, we used an Edison electric phonograph motor, whose speed is regulated by means of a governor as indicated at *d* in Fig. 2. When the speed of the motor tends to increase, this governor introduces a resistance into the circuit and does not break the circuit as is the case with the Helmholtz motor.

At *e* is shown a slide-rheostat by means of which the speed of the motor is regulated in accordance with the second demand. The constancy of speed of rotation is satisfactory for the periods employed. The mean variation for 17 determinations covering a period of 11 minutes was calculated to be .9%. Upon the steel cylinder of the phonograph-record, whose end is seen in the upper left corner of the engraving, is mounted a belt-groove. This groove affords a tight grip for the belt and keeps the belt in place on the cylinder. The belt runs over a pulley which is fastened on a spindle at the

forward end of which are seen the two overlapping cams, *a* and *b*, held in position by means of a knurled nut. This spindle is mounted on a base separate from the motor. The cams are made of 1/32″ sheet brass, and can be readily replaced by any other type of cam desired. These cams serve as a basis for the interruption of the secondary circuit and for the consequent production of the two-membered rhythm investigated in this experiment. At *c* is seen the lever made of amalgamated sheet copper. This lever is tripped by the cams. To its right is a duplicate lever which may be used when another circuit is to be interrupted in alternation with the first. In this case another arrangement of the cams used becomes necessary. As the cams are shown, *b* is mounted in front of *a* which is approximately a sextant and carries on its circumference a black pointer seen directly above lever *c*. This pointer indicates, upon the graduated arc *b*, the amount of revolution of *b* over *a*. The cams are cut to give a long interval of 180° shown in the upper circumference of *b* and a short interval of 60° represented by the arc of *a*. On either side of *a* as shown and, of course, uniting in front of the arc of *a*, are depressions corresponding to the two members of the rhythm, *i.e.*, stated a little differently, the lower circumference of *b* is a continuous depression, interrupted by the projection of cam *a*. To whatever extent, therefore, *a* is rotated to the right or to the left over the circumference of *b*, to that extent will the temporal rhythm become iambic or trochaic. At the position shown, the rhythm delivered will be approximately a spondee. In this way is the sixth requirement met. The lever dips into a mercury cup, shown beneath it, whenever a depression occurs in the circumference of the cams. This sort of contact is, of course, one of the very best obtainable and meets the fifth condition. In like manner is the fourth requirement satisfied, because, as the cams in their rotation very quickly act upon the shorter arm of the lever, the more quickly is the longer arm lifted out of the mercury. The eighth demand is satisfactorily met by the shape of the cams themselves. Both outer circumferences of these cams are of constant length regardless of their shifting. The requirements as to the accuracy of the measurement of the speed of the motor and the length of the intervals of contact and of non-contact are adequately met by putting in series with the circuit interrupter an electric time-marker together with a time-fork, or other recording apparatus, and a kymograph, or the Hipp chronoscope. There is ample provision for inserting another circuit in which the

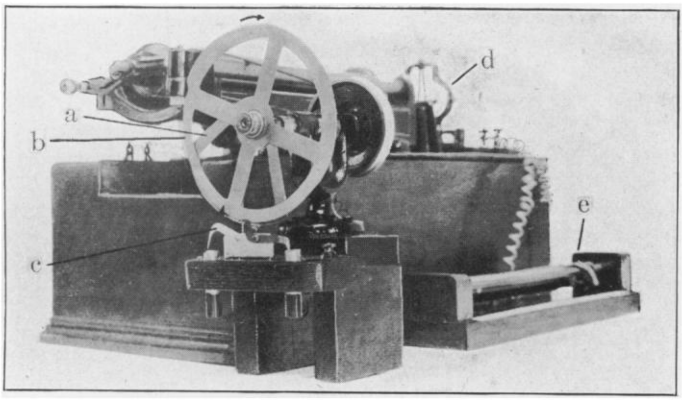

Fig. 2.—Rhythm Interruptor.

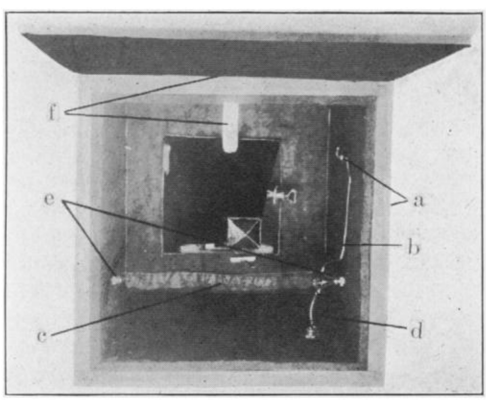

Fig. 3.—Rhythm Box Controller.

second lever may be used, as when a circuit of comparatively high resistance is to alternate with one of less resistance in order to obtain a difference in the intensity of the two rhythm members, or as when a circuit connecting with a source of sound of higher pitch is to alternate with a circuit connecting with a source of sound of lower pitch, in order to obtain differences in pitch between the two members. By the addition of the proper number of cams and by inserting cams of the proper shape, rhythms of a higher order than the two-membered series used in this experiment may be produced.

Rhythm-box Controller

(Fig. 3)

In order to produce an unintensified sound at the beginning of a rhythm series after an interval of no sound by means of a Stoelting rhythm-box, it became necessary to modify the apparatus in the manner shown in Fig. 3. As the apparatus is put on the market, it consists of a square felt-lined box, high enough to contain an ordinary metronome and wide enough to allow the metronome pendulum to execute its widest excursion. The cover of this box is hinged at the back and it is opened slightly and noiselessly by means of a series of connecting rods and a finger-key. After the metronome is started in the box and the cover is closed, a faint ticking is heard until a depression of the finger upon the key raises the cover and intensifies the sound. If, then, there is occasion to start the rhythm series with an unintensified metronome click after an interval of no sound, or if it becomes necessary or convenient to start and stop the metronome clicks at any desired points in the rhythm series, recourse must be had to a device that will start and stop the metronome when the cover is closed.

The view in the photo-engraving is from above. The metronome stands on a piece of heavy harness-felt in which a triangular hole is cut to receive the three feet mounted on the base of the metronome, thus to insure the accuracy of its position. In front of the pendulum is a padded brass rod (*e*), pivoted at *e*, in shape like the wire of a long package-handle. At the right before it bends down to its pivot, a steel tension spring (*d*) is attached and fastened in the same plane to the front side of the box. At this place, also, is pivoted a rod (*b*) which connects the padded brass rod (*c*) with the operating lever (*a*). This rod (*b*) is bent to the right to avoid interference with the swinging of the metro-

nome pendulum. The operating lever (*a*) passes through the side of the box and pulls against the spring (*d*). When moved toward the back of the box, it causes the padded brass rod (*c*) to press against the metronome pendulum, and when given an additional downward thrust past its own 'dead-center' it locks the device. At *f* is indicated a rubber-covered steel spring and protecting pad. These are attached to relieve pressure and to avoid the noise of the dropping cover.

The entire device proved to be noiseless in operation and in other respects very satisfactory to the experimenter during months of continuous use. With practice the experimenter was able by its means to stop the pendulum at the end of its swing so that it started properly in response to the mechanism of the metronome when the operating lever (*a*) was released.

CHRISTIAN A. RUCKMICH.

Rhythm Hammer

(Fig. 4)

This piece is adapted to drill and demonstrational purposes. It is made up of a steel hammer and anvil, a set of adjustable cams for producing various rhythmic patterns, and a friction speed-gear. The frame is 13½ in. x 19 in. x 7½ in. It has cast-iron sides and steel cross-bars, and it is securely set upon a heavy 3-ply oaken base. A longitudinal shaft, fitted to the centre of the friction-wheel, accommodates as many as nine cams. The cams are slipped into the key-way of the shaft by removing two knurled set-screws which hold the end cross-bar (*a*). Any one of them may be instantly adjusted in the plane of the hammer and thus set into action. The height of fall of the hammer is provided for by two or more radial drops cut in the cam; *e.g.*, a simple 2-rhythm is produced by one high and one low drop set at opposite ends of a diameter, a simple 3-rhythm by one high and two low drops spaced at 120°. Since the hammer may be released (by withdrawing a bit of felt from the anvil-head) upon any beat of the rhythmic unit, two cams suffice for the five primary rhythms. The other cams are reserved for special stimulus-patterns. The apparatus provides, moreover, for a universal cam fitted with slotted eccentric arcs for the production of small temporal and intensive variations. (This cam is not figured.) An adjustable coiled spring (*b*), which fastens the hammer-rod to its forked steel support, determines the general intensity of the pattern. Since the anvil (*c*) and the hammer-support (*d*) are alike capable of

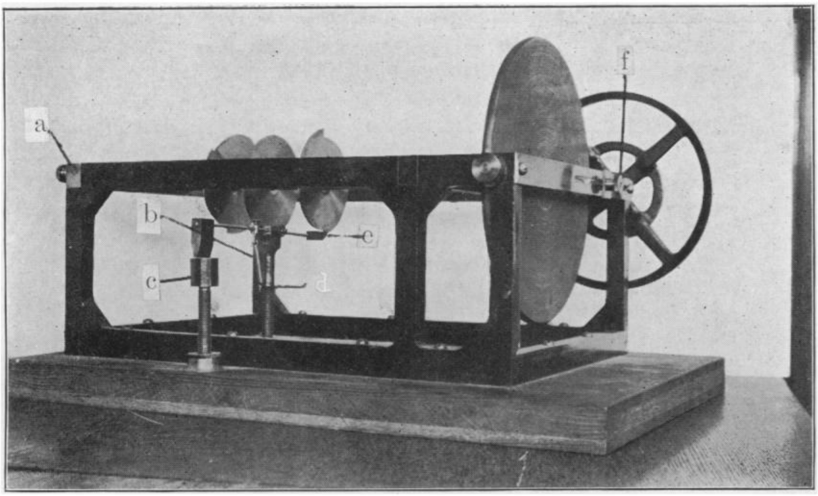

Fig. 4.—Rhythm Hammer.

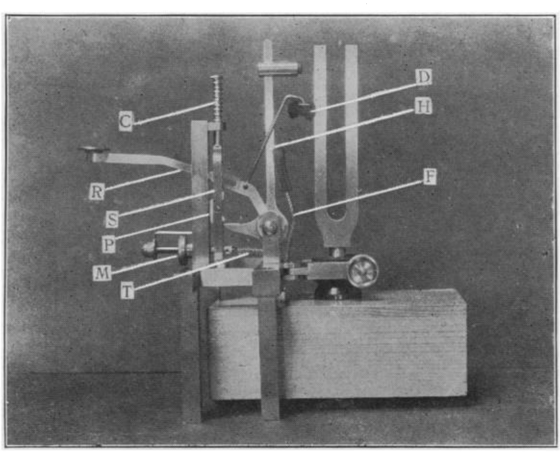

Fig. 5.—Automatic Tuning-Fork Hammer.

vertical adjustment, cams of various diameters may be used. The tail-piece (*e*) of the hammer-rod is made of fibre to eliminate the noise of contact with the brass cams. The friction-gear and the double pulley-wheel together allow for a variation in speed within the limits 1 to 8. The setting of the drive-wheel against the friction-plate is indicated by a scale-bar (*f*) at the right of the instrument. The piece may be actuated either by a small motor or by a gravity-gear. It is suitable for large or small lecture-room or for the laboratory.

MADISON BENTLEY.

Automatic Tuning-Fork Hammer

(Fig. 5)

As first designed, this instrument was intended to serve as a single unit in a series of eight forks for demonstrational use. It has, however, been found to be very useful also in experimental work. It combines the following features.

(1) The fork is struck rapidly and precisely by a single movement of the hand. It is thus possible to control with accuracy the time of striking. Two or more forks may be so struck together or in succession as to give an interval or a simple melody. A single fork may be repeatedly sounded at very short intervals,—an advantage not shared by those mechanical strikers in which the hammer has to be set by hand before it can be released for the blow.

The mechanism includes a hammer-piece (H) and a key-rod (R) separate, but pivoted about the same axis, the latter being forked about the former. The key-rod passes through a slot in the slide (S) which is free to move vertically in ways fastened to a vertical post. The slide carries a small roller, which works in a slot cut in the key-rod, so that, when the key-rod is depressed, the slide is also depressed. Below the roller the slide carries a pawl (P) which engages, when the slide is depressed, with the horizontal arm of the hammer-piece, until, upon being depressed further, the arm is released by clearing the pawl. Thus the hammer, a rubber cushion set in the end of a steel cylinder, is suddenly released, after being brought away from the fork against the action of the tension spring (T). After once striking the fork, the hammer is prevented from remaining in contact or from striking again by the flat steel spring (F). The slide and the key-rod are elevated after depression by the compression spring (C), the pawl being so pivoted as to slip by the arm of the

hammer-piece in the upward stroke. Both pawl and hammer-piece are made of tool steel; the other parts are of brass.

(2) The intensity may be accurately controlled. This is accomplished by a micrometer (M) to which the end of the tension spring is fastened. It is possible to get any intensity from zero up to a maximal strength. For the greater intensities, stronger springs can be used. In this way, the apparatus can be employed in work with the intensive limens.

(3) The fork is automatically damped by the felt damper (D) which is brought into contact with it when the key is released. As long as the key is depressed, however, the fork sounds. This arrangement is useful when different forks are to be struck in rapid succession without fusing, or when a melody is to be given. If desired, the damper can be readily removed, or can be made only partially effective by loosening the compression spring (C).

(4) The hammer can be quickly applied to almost any fork by fastening the wooden base on the resonance box, in which the fork fits, into the felt-covered clamp on the hammer-frame. The position of the hammer on its stem can be varied to the best striking position by means of a set-screw, and the distance of the hammer from the fork can be altered by loosening or tightening the tension spring (T).

(5) The device is supported upon two horizontal rods, which can be made of proper length to bear any number of units desired. It was in such a form that it was planned to build the eight units into a tuning-fork piano.

A single unit can be constructed of brass and steel with sufficient precision to insure accuracy in experimental work for about twenty-five dollars.

EDWIN G. BORING.